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Comparison of results obtained using the injection method of preparation of solid amorphous alloys with and without suction

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ABSTRACT

Purpose: The study compares the structure and properties titanium alloy Ti-6Al-4V produced by injection method allowing the production of massive amorphous materials in two varies – with and without suction.

Design/methodology/approach: Samples were produced form titanium alloy Ti-6Al-4V produced by injection method. Structures and properties were compared of the same alloy but with different conditions in production process – with and without suction. To achieve the objective perused the following tests were carried out: study of phase composition by X-ray diffraction, observation of microstructure by using optical microscope and SEM, study of surface geometry – roughness, abrasion resistance tests and microhardness tests.

Results: Microstructural studies have allowed to observe that the titanium alloy Ti-6Al-4V produced by injection method in both varies – with and without suction during injection to copper mold, has structure partially crystalized – nanocrystalline. In structure occur the crystal nuclei and lack of arrangement and regularity. The study of microhardness showed 100 HV 0.1 units higher hardness value in the embodiment with suction in comparison to the variant without suction. Titanium alloy Ti-6Al-4V produced with suction has better abrasion resistance in comparison with same alloy without suction. Alloy produced with suction has lower development area.

Originality/value: The paper presented studies of massive amorphous and nanocrystalline alloys produced by alternative method – injection casting in two variants – with and without suction. That kind of production allow produced alloys with same chemical composition as commercial but with far better properties.

Keywords: Titanium alloy Ti-6Al-4V; Production of amorpous and nanocrystalline alloys by injection casting

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MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

Producing of massive amorphous alloys by injection casting characterized by injection liquid alloy to copper mould, which is radially cooled under gas pressure. Production process has require following operations: prepared ingot is placed in a quartz capillary, where is melted by induction. After melting liquid alloy is pressing to copper mould by gas pressure, copper mould is radially cooled. That method allows produce massive amorphous alloys to the size of a few millimetres, which depends on the chemical composition, because not all materials used in injection casting have amorphous structure entire cross-section [1,2]. Scheme of device which was used to produce massive amorphous materials by injection casting is shown in Fig. 1.

That method allows: performing a full production cycle for a short period of time, obtaining a high vacuum, rapid cooling copper mould preparing amorphous solid samples, a continuous temperature control of the copper mould in the range of liquid nitrogen temperature to room temperature [1,3,4].

2. Material and methodology

Tests samples were produced by injection method with two variants: with and without suction. Material which was used to produce samples is titanium alloy Ti-6Al-4V. Chemical composition of that alloy is shown in Table 1.

Microstructure of obtained samples were observed by using SEM and optical microscope Axiovert 25 from Carl Zeiss company with camera. In order to determine chemical composition observation by using SEM with EDS was carried out.

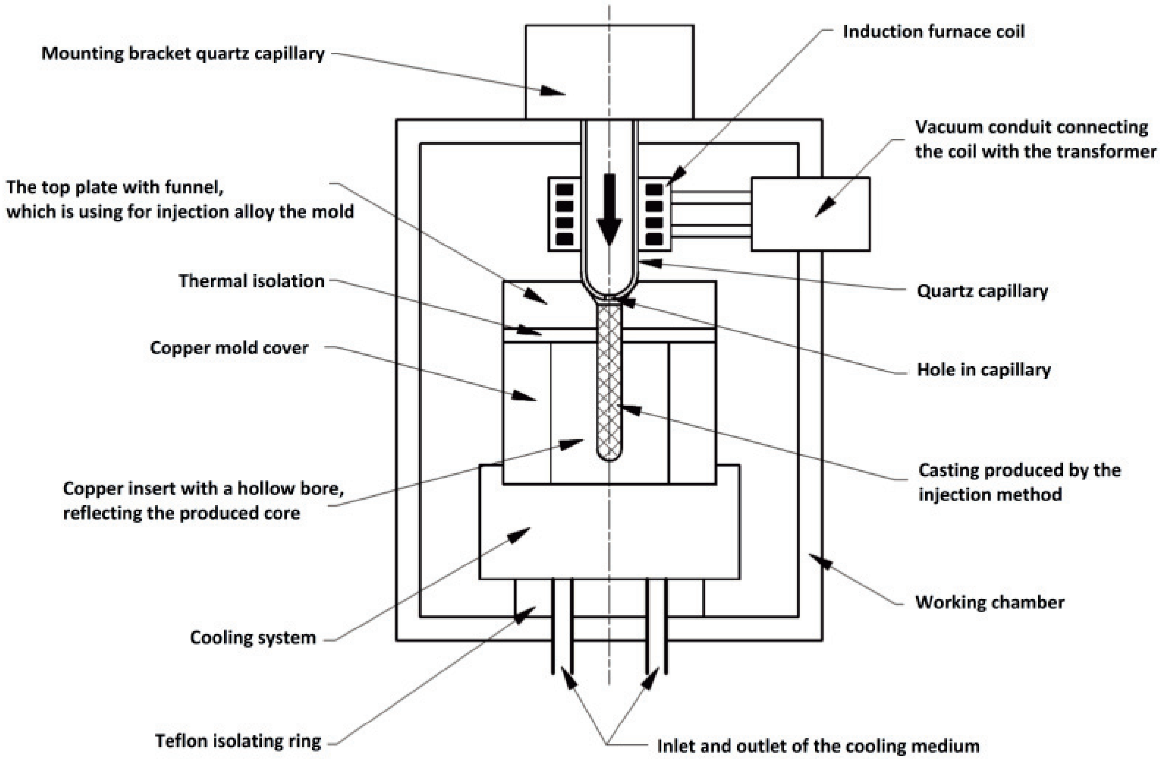

Fig. 1. Scheme of device which was used to produce massive amorphous materials by injection casting

Table 1.
Chemical composition of titanium alloy Ti-6Al-4V [5]

Chemical composition	Al	V	C	Fe	O	N	H	Ti
Percentage	6.00	4.00	0.03	0.1	0.15	0.01	0.003	rest

In order to determine roughness surface, tests on profilometer Hommel T-1000 were carried out. Determination of surface roughness is made in contact with the test surface by the engagement of a needle with a differential measurement system. Mechanical properties of produced samples were carried out by abrasion resistance test. This test was performer by using ball-tester with zirconia ball through a limited time with a predetermined speed and a predetermined load level of abrasion resistance was determined by size of wipe area.

Micorhardness of the samples were tested, test conditions: Vickers hardness – load 970 mN – HV0.1. Tests were carried out on half-pneumatic microhardness machine FM-7 FUTURE-TECH.

3. Results

Images of microstructures titanium alloy Ti-6Al-4V produced by injection method in one case with suction, the other without, were made by scanning electron microscopy. These structures shown in Figure 2. in Figure 3 shown images which were made on optical microscope.

Microstructural observations of titanium alloy produced by injection with two variants – with suction and without suction. Observations using scanning electron microscope breakthroughs prepared samples can be observed, that the sample prepared by injection without the use of suction has a much greater number of pores than in the case with suction. During studies of titanium alloy produced by injection method, can be observed. The first of these structures characterized by lack of order and regularity. The presence of partial crystallization of the sample indicates the creation of embryos crystallites, contracting and expanding in dendritic structure.

Microscope images after abrasion resistance test are shown in Figure 4, where all of samples were tested for a time half an hour.

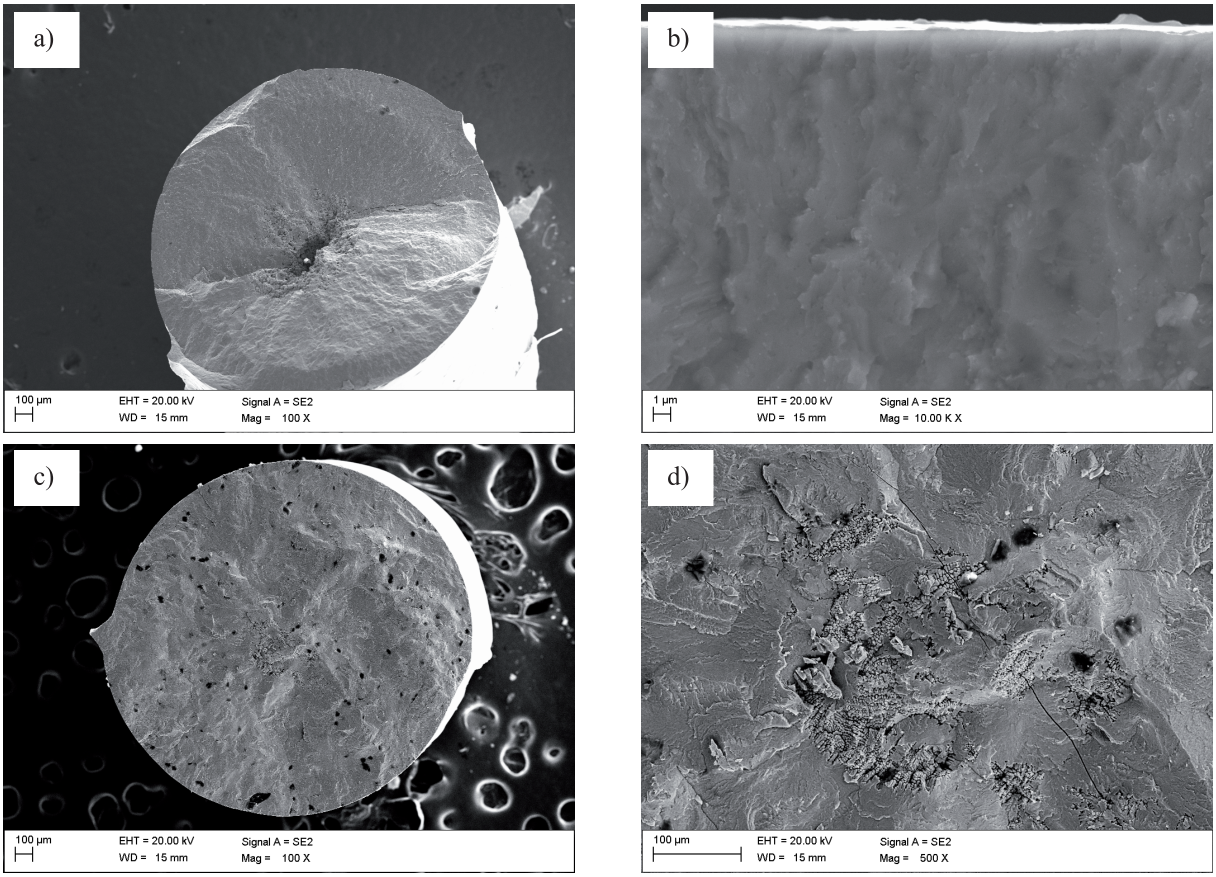

Fig. 2. Microstructures of titanium alloy Ti-6Al-4V produced by injection casting a) and b) with suction c) and d) without suction, SEM

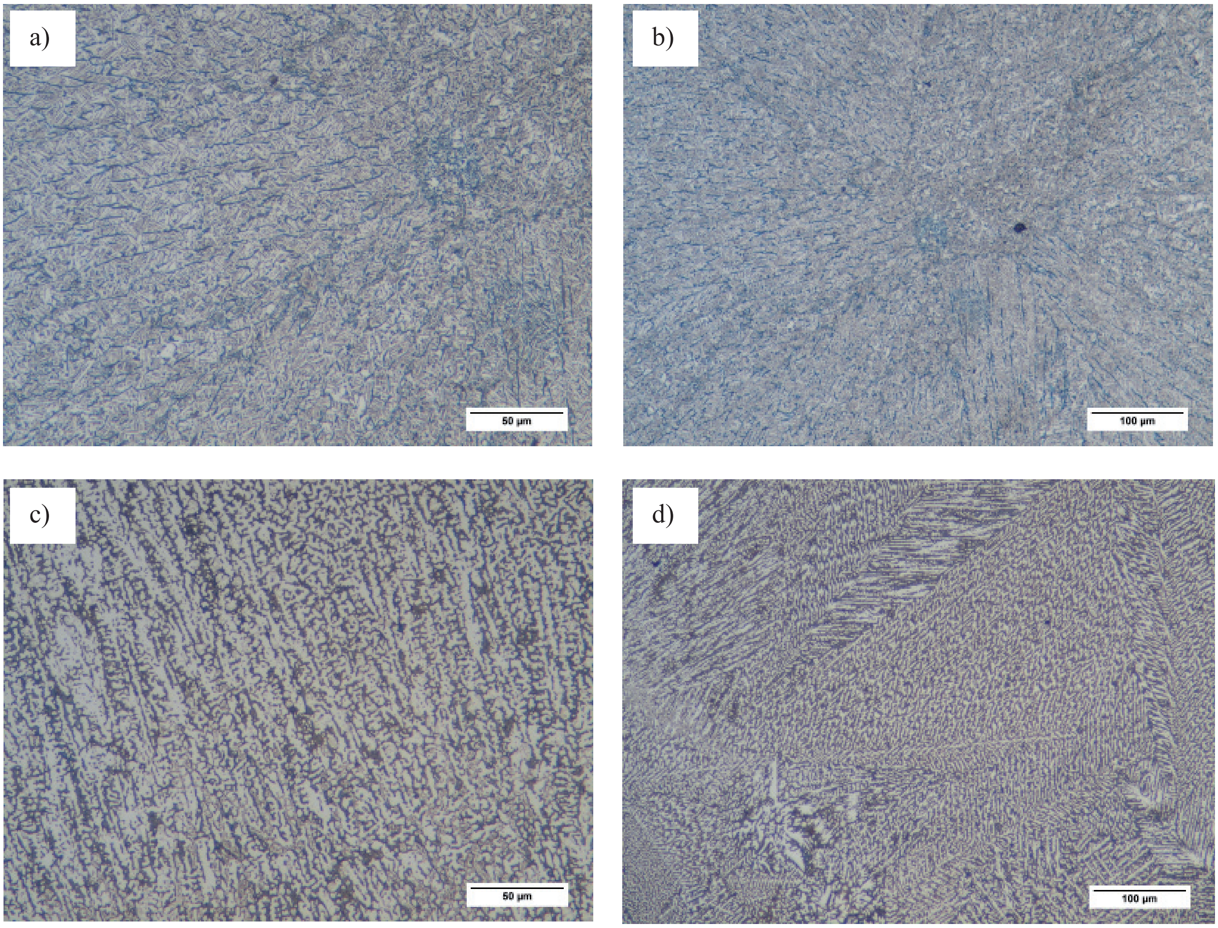

Fig. 3. Microstructures of titanium alloy Ti-6Al-4V produced by injection casting a) and b) with suction c) and d) without suction, optical microscope

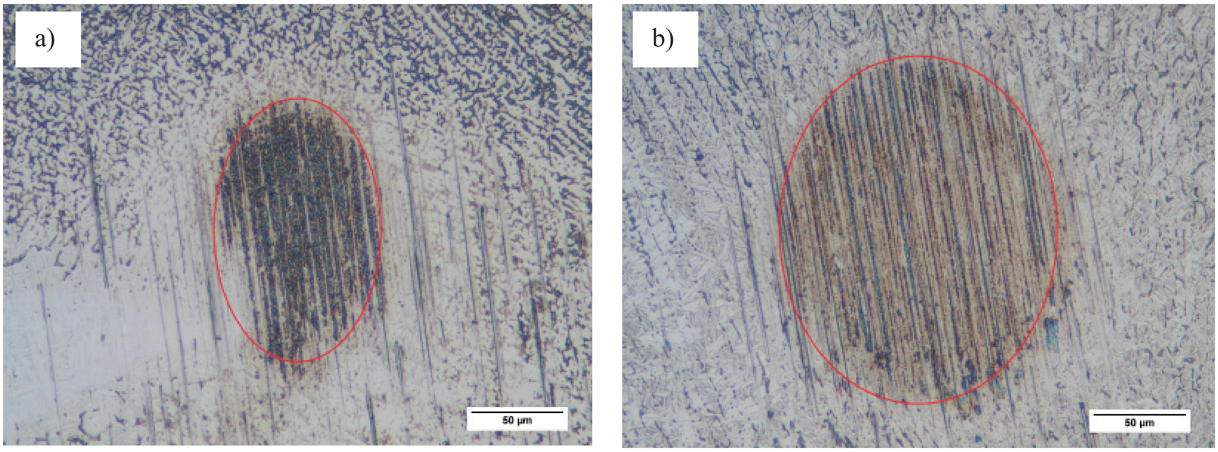

Fig. 4. Microscope images of areas of wear caused on the surface of each sample as a result of abrasive wear a) with suction and b) without suction, optical microscopy

Microstructural observations of the surface of the samples subjected to the influence of zirconium ball led to the conclusion, that the sample formed without the suction injection method has a higher abrasion resistance than the same alloy produced by the same method with using suction. Microhardness results shown in Figure 5 with using column chart.

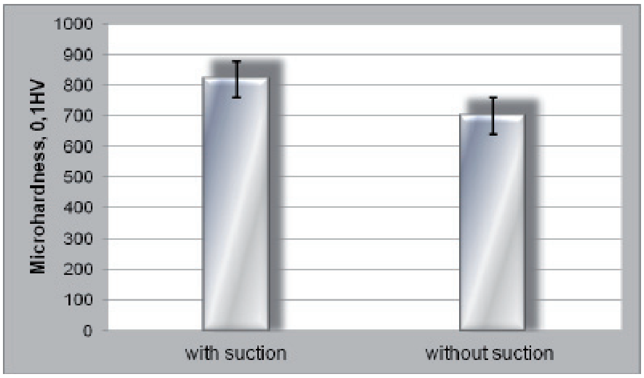

Fig. 5. Microhardness results

Microhardness tests carried out have shown for the sample of titanium alloy Ti-6Al-4V produced by injection with suction, that its hardness is higher than 100 HV0.1, than the same alloy produced by the same injection method, but without suction. The arithmetic mean of the measurements of microhardness of samples were prepared by injection using suction was 820.1 HV0.1 and prepared by the same method but without suction 700.4 HV0.1.

The results of measurements of surface roughness parameters are listed in Table 2. Surface roughness profiles are shown in Figure 6.

Profilometry analysis allowed the identification of indicators of roughness. Higher rates of surface roughness characterized samples produced by injection without suction. Sample obtained in this way is almost seven times higher roughness (R_a), than the samples obtained by the same method with suction. Value R_a of sample without suction is equal 2.31 µm, and with suction is equal 0.33 µm. Parameter R_q talking about the mean square elevation profile for the sample prepared without suction is 3.2 µm, and for sample with suction 0.5 µm, which is more than six times smaller than in the case of the samples obtained without suction.

Table 2.
Results of measurements of surface roughness parameters

Sample	Measurement number	Parameter						
		R_q	R_t	RS_m	R_z	R_a	R_p	R_{max}
Injection with suction	Measure I	0.58	3.09	0.09	1.19	0.31	1.69	3.09
	Measure II	0.41	2.07	0.08	1.13	0.34	1.13	2.07
	Measure III	0.52	3.22	0.07	1.59	0.33	1.37	3.22
	Average	0.5	2.8	0.08	1.3	0.33	1.40	2.79
Injection without suction	Measure I	3.06	17.13	0.06	11.53	2.38	7.38	15.36
	Measure II	3.22	17.60	0.06	14.16	2.49	7.84	15.78
	Measure III	3.33	17.27	0.06	13.09	2.05	7.08	15.27
	Average	3.20	17.33	0.06	12.93	2.31	7.43	15.47

where:
R_q – square average elevation profile,
R_t – total height of the profile,
RS_m – the average width of the groove profile elements,
R_z – greatest height profile,
R_a – arithmetic average elevation profile,
R_p – the height of the highest peak of the profile,
R_{max} – the maximum deviation.

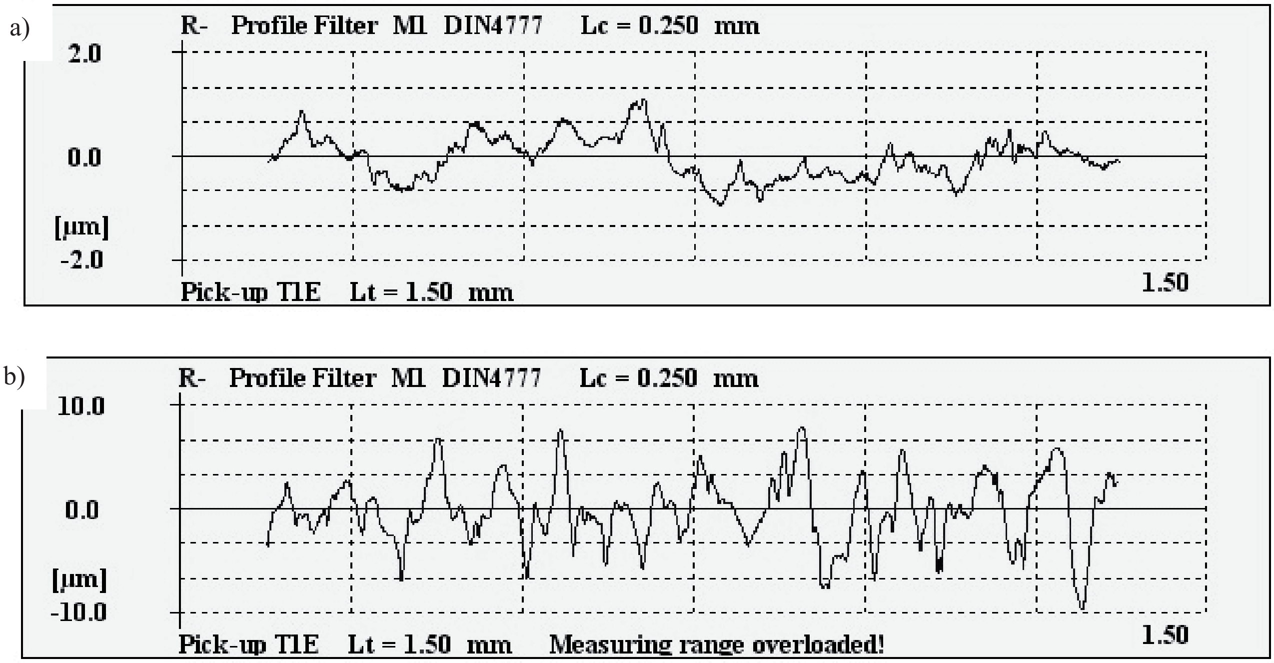

Fig. 6. Surface roughness profiles of titanium alloy samples Ti-6Al-4V produced by injection a) with suction, b) without suction

4. Conclusions

Variants of the injection method, obtaining a titanium alloy Ti-6Al-4V affect the nature of the structure obtained, and thus the properties of the material. Rapid cooling of the samples by injection molding allows a partially amorphous structure, with a nanocrystalline structure with a lack of order in the structure.

Evaluation of surface topography allowed to conclude that the greater development of the area is characterized by an alloy formed by the injection without of suction. The development of the surface of a sample obtained in this variant is incomparably greater, than in the case of injection of suction, as many as over six times.

Microhardness analysis showed that the alloy obtained by injection with suction exhibits a higher hardness over 100 HV0.1 compared with the same alloy formed by the same method, but without suction.

Tests of resistance to abrasion allowed to determine that the improved resistance to wear a sample prepared by injection with suction during the injection of material into the mould.

According to the research, titanium alloy Ti-6Al-4V produced by injection with suction during the injection of material into the mould shows significantly better properties than the same alloy produced by the same method but without suction. It has a nanocrystalline structure, a higher hardness, better wear resistance and smoother surfaces. The material produced by this method can be a potential material for use in many fields of engineering, requiring high hardness, good abrasion resistance with a smooth surface at the same time.

References

[1] M. Nabiałek, Preparation and properties of amorphous and nanocrystalline alloys of iron, Czestochowa University of Technology Publishing House, Czestochowa, 2012 (in Polish).

[2] M. Nabiałek, S. Borkowski, Preparation microstructure and magnetization process of bulk amorphous and nanocrystaline iron alloys, Zilina Publishing House, Katowice, 2010.

[3] M. Nabiałek, M. Szota, The production method of bulk amorphous alloys based on 3d transition metal group with high microhardness, Materials Engineering 32/4 (2011) 620-623 (in Polish).

[4] M. Nabiałek, L. Jeziorski, M. Szota, J. Jędryka, Application of molten metal suction method for Ti-Zr based partially crystallized alloys manufacture, Materials Engineering 33/4 (2012) 264-266 (in Polish).

[5] ISO 5832/3. Implants for surgery. Wrought titanium-6aluminium-4 vanadium alloy. ASTM F-136-Specification for Titanium-6Al-4VELI Alloy for Surgical Implant Applications.